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Categorical & coordinate spatial information: Can they be disentangled in sketch maps?

Antonella Lopez[a,b,*], Albert Postma[b], Andrea Bosco[a]

[a] Department of Educational Sciences, Psychology, Communication, University of Bari, Italy
[b] Helmholtz Institute, Experimental Psychology, Utrecht University, the Netherlands

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ABSTRACT

Humans tend to encode the environment by means of two types of spatial relations: coordinate (metric) and categorical (nonmetric). The present research contributes to methods for disentangling the contribution of categorical and coordinates spatial relations in sketch maps and investigates the role of familiarity with spatial information in accurate encoding of these spatial relations. The results of three experiments show that as familiarity with spatial layout increases, differences between categorical and coordinate spatial relations tend to decrease. Moreover, they reveal that the way in which spatial information has been acquired – through navigation or map study - affects performance. Navigation favours coordinate encoding, while map study favours categorical encoding. Finally, gender differences did not emerge when spatial information was acquired through navigation, but they were present in the case of map study acquisition. In conclusion, it seems possible to extract reliable and independent information on both categorical and coordinate spatial mental representations using sketch maps.

1. Introduction

Most actions that humans perform depend on their sense of space. The human sense of space in turn is formed by acting and interacting with the outside world. This interconnection allows humans to acquire, to organize and to use spatial knowledge. Spatial knowledge acquisition is an important human skill that includes the ability to encode, store and retrieve spatial information (Aguirre & D' Esposito, 1999; Piccardi, Palmiero, Bocchi, Boccia, & Guariglia, 2019). In this way, humans form flexible internal spatial mental representations, like cognitive maps, containing information about relationships, such as distances, positions and directions between landmarks (Tolman, 1948; O'keefe & Nadel, 1978; Wolbers & Hegarty, 2010). The information contained in these representations includes both the metric and nonmetric spatial properties of environments (Goldin & Thorndyke, 1982; Ruotolo, Ruggiero, Raemaekers, Iachini, van der Ham & Fracasso, 2019; Thorndyke & Hayes-Roth, 1982). Globally, spatial properties include location, size, distance, direction, separation and connection, shape, pattern, and movements (Lopez, Caffò, Spano, & Bosco, 2019). Humans use these properties to measure and describe space in order to build mental spatial representations of the environment (Piccardi et al., 2018; Postma & Koenderink, 2016).

We can distinguish two main ways in which we build spatial representations. First, environments can be learned by people moving through those environments and directly sensing spatial features while they are driven by goal-directed exploratory behaviours (Noordzij, van der Lubbe, & Postma, 2005). In addition, humans can acquire information via symbolic sources, such as maps or language (Montello & Freundschuh, 1995). It is known that spatial information acquired through repeated exposures to the environment allows for consolidation of spatial memory traces (Burgess, 2008). In this way, people improve their spatial mental representations making them more factually correct. This internal mental representation can then be translated into external representations such as maps. Thus, it can be claimed that when people's level of familiarity with spatial information improves, they produce more precise representations of the environment.

Spatial relations form the building blocks of environmental representations. Two main classes of references can be distinguished: categorical and coordinate (Kosslyn, 1987). Categorical spatial relations refer to the relative positions of objects in space, using general spatial labels such as right and left, or above and below. Humans use categorical spatial relations in order to describe spatial situations and memorize the locations of objects. Coordinate spatial relations refer to the metric distances between them: an object might be placed 3 cm

* Corresponding author. Department of Educational Sciences, Psychology, Communication, University of Bari, Via Crisanzio 42, 70122, Bari, Italy. Tel.: +39 0805714713.
E-mail addresses: antonella.lopez@uniba.it (A. Lopez), A.Postma@uu.nl (A. Postma), andrea.bosco@uniba.it (A. Bosco).

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from one object and farther away from another object. Humans use coordinate spatial relations in order to perform motor actions and estimate distances (e.g., Bullens et al., 2010; de Goede & Postma, 2015; Hellige & Michimata, 1989). At a neural level, categorical and coordinate spatial relations are thought to involve, as claimed by Kosslyn (1987), different hemispheric lateralization: categorical relations show a left hemispheric advantage, while coordinate spatial relations depend mainly on the right hemisphere.

Until now the categorical and coordinate paradigm has been applied using very simple tasks such as the Hellige and Michimata standard dot bar task (1989), and arrangements of objects or identity tasks (e.g. Ruggiero, Frassinetti, Iavarone, & Iachini, 2014; Laeng, 1994; van Asselen, Kessels, Kappelle, & Postma, 2008; Kessels, Postma, & de Haan, 1999). The results have shown that categorical judgments are easier than coordinate judgments (Bruyer, Scailquin, & Coibion, 1997; Klencklen, Després, & Dufour, 2012; Trojano, Grossi, Linden, Formisano, Goebel & Cirillo, 2002), especially when they are combined within an allocentric reference frame (Jager & Postma, 2003; Ruotolo, van Der Ham, Iachini, & Postma, 2011). In the present study, we used the categorical/coordinate distinction in a new field involving sketch maps. Originally, this graphic schematization of space was described by Lynch (1960) with the use of five key elements: paths, edges, districts, nodes, and landmarks. Sketch maps have been used to investigate geographical and spatial knowledge, by requiring participants to make drawings based on mental representations of a spatial configuration they have explored (Blades, 1990; Golledge, 2002; Saarinen & Levi, 1999). They can be considered an important tool for evaluating the spatial knowledge a person possesses (Wise & Kon, 1990). As reported by Schwering et al. (2014), sketch maps have been used to investigate how humans memorize spatial information. Sketch maps can be considered a reliable method to externalize internal (mental) images of the environment (Blades, 1990; Howard, Chase, & Rothman, 1973; Kerst, Howard, & Gugerty, 1987; MacKay, 1976). Therefore, we can consider sketch maps as external representations of cognitive maps, specifying how sketchers remember the spatial world.

From a methodological perspective, several authors have derived qualitative and quantitative information from sketch maps and metric maps. Metric maps are more precise than sketch maps given that they contain relevant spatial objects, not ignoring the accurate geometries and the exact metric details between objects (Wang & Schwering, 2009). Schwering et al. (2014) have developed SketchMapia framework that offers a qualitative approach to align spatial objects and spatial relations in sketch maps with metric maps. Moreover, The Double Cross calculus by Freksa (1992) has been proposed in order to evaluate qualitative information about spatial configurations, more specifically the qualitative position of one point with respect to an oriented line segment. On the other hands, The Gardony Map Drawing Analyzer (Gardony, Taylor, & Brunyé, 2016) was a software package for computational sketch map analysis, based on pairwise comparisons between landmarks, for calculating bidimensional regression parameters (Friedman & Kohler, 2003). Bidimensional regression is considered the preferred method for estimating mapping relations between two planes on the basis of regression modelling (Carbon & Leder, 2005; Tobler, 1965).

Several researchers have investigated the relationship between an individual's accuracy on cognitive map tasks and their level of familiarity with to-be-recalled layouts (e.g., Lloyd & Patton, 2011). Frequent experience with spatial targets allows people to precisely know where a target landmark is located in map-like tasks, and in perceptual and visual search tasks, and to solve difficult distance knowledge problems (e.g., Desimone & Duncan, 1995). So, familiarity with a physical environment allows people to solve location tasks (de Goede & Postma, 2015). As already shown by (Lopez, Caffò, & Bosco, 2018, 2019), people - even those that normally find it difficult to learn new environments - can easily solve position tasks based on well consolidated information. In particular, familiarity allows learning more precise coordinate information for city locations (Lloyd & Patton, 2011).

Another factor that has extensively been investigated in the categorical and coordinate paradigm is the role of gender. Generally, it has been reported that males outperform female participants in tasks based on coordinate judgements, while females are better able to perform categorical tasks (e.g. Postma, Izendoorn, & De Haan, 1998; Voyer, Postma, Brake, & Imperato-McGinley, 2007), but this evidence cannot be considered consistent (van der Ham & Borst, 2011). Moreover, as stated by Palermo et al. (2012) these differences might be attributable to different levels of familiarity with landmarks.

The general aim of the present research was to investigate the possibility of identifying categorical and coordinate relations in sketch maps and by taking into account factors affecting the encoding of spatial relations. In the present study, our interest focused only on location of landmarks, as they are the most salient and traditionally studied spatial objects in sketch maps (e,g., Sorrows & Hirtle, 1999; Richter & Klippel, 2002; Filomena, Verstegen, & Manley, 2019). In order to achieve the general purpose of the present research, we performed three studies, as follows.

Experiment 1 aimed to evaluate categorical and coordinate spatial relations (an integrated outcome of spatial information regarding distances and positions), with particular attention to mental spatial representations derived from geographical areas acquired through direct navigation as well as from the study of maps. We hypothesized that experiencing distances in a perceptual and goal directive way through navigation (Campus Geographical Area) could enhance the encoding of coordinate components compared with the knowledge achieved by map study (Apulia and Italy Geographical Areas).

Experiment 2 examined mental representations based mainly on the study of maps and considered how levels of familiarity with the environment affected encoding accuracy. We wanted to assess the effect of familiarity according to three geographical areas chosen on the basis of their supposed familiarity (Italy, Northern Europe, World Geographical Areas). We hypothesized the higher the level of familiarity, the smaller the difference in accuracy between categorical and coordinate information should be.

Experiment 3 was also devoted to investigating the role of familiarity with maps. We wanted to explore how spatial relations were encoded by two groups of young participants from different European countries. Moreover, we wanted to see whether, in line with previous research, categorical judgements are indeed easier than coordinate judgements, even for tasks based mainly on map study (e.g., Bruyer et al., 1997). We expected a smaller difference between categorical and coordinate spatial relations for sketch maps referring to the participants' own country (The Netherlands and Italy Geographical Areas) and referring to larger geographical areas encompassing the participants' own country (Northern and Southern Europe Geographical Areas), respectively. Finally, in the three experiments we highlighted the role of familiarity in the categorical and coordinate distinction by also noticing if gender differences existed for familiar maps.

2. General method

2.1. Materials

2.1.1. Geographical areas thought as stimuli

The *Campus Geographical Area* (see Fig. 1a, Experiment 1) included three very familiar landmarks: the entrance of the Student Center, the entrance of the Department and the stairs of the Salone degli Affreschi inside the main building of the University. The walkable area of the campus was approximatively 6.6 km^2 (see distances in Fig. 1a). The stated scale (relationship between distances on a map and distances in real life) was 1 cm = 19 m. The way in which participants had learnt the entire area was mainly through repeated navigation experiences.

The *Apulia Geographical Area* (see Fig. 1b, Experiment 1) included three landmarks: Bari, Brindisi and Taranto. The area investigated was

Fig. 1. Target Geographical areas and distances between landmarks: a) University Campus; b) Apulia Region; c) Italy. Illustrations free downloaded from Google Maps.

approximately 2450 km^2 (see distances in Fig. 1b). The stated scale was 1 cm = 14.5 km. The way in which participants had learnt the entire area was most likely mixed, through both navigation and map study experiences.

The *Italy Geographical Area* (see Fig. 1c, all experiments) included three landmarks: Genoa, Naples and Cagliari. The area of the region investigated was approximately 128600 km^2 (see distances in Fig. 1c). The stated scale was 1 cm = 110 km. The way in which participants had learnt the entire area was mainly through map study.

The *Netherlands Geographical Area* (see Fig. 2a, Experiment 3) included three landmarks: Groningen, Maastricht and Den Haag. The area of the country investigated was approximately 16700 km^2 (see distances in Fig. 2a). The stated scale was 1 cm = 18 km. The way in which participants had learnt the entire area was mainly through map study.

The *Northern Europe Geographical Area* (see Fig. 2b, Experiments 2 and 3) included three landmarks: Paris, London and Amsterdam. The area of the country investigated was approximately 63012 km^2 (see distances in Fig. 2b). The stated scale was 1 cm = 162 km. The way in which participants had learnt the entire area was mainly through map study.

The *Southern Europe Geographical Area* (see Fig. 2c, Experiment 3) was composed of three landmarks: Rome, Lyon and Palma de Mallorca. The area of the country investigated was approximately 255000 km^2 (see distances in Fig. 2c). The stated scale was 1 cm = 228 km. The way in which participants had learnt the entire area was mainly through map study.

The *World Geographical Area* (see Fig. 2d, Experiment 2) included three landmarks: New York, Rio de Janeiro and Cape Town. The area investigated was approximately 16M km^2 (see distances in Fig. 2d). The stated scale was 1 cm = 1166 km. The way in which participants had learnt the entire area was mainly through map study.

2.2. Task difficulty

Considerable effort was made to ensure the difficulty of these different tasks was comparable. Task difficulty was evaluated from both the categorical and coordinate point of view. Starting from the actual position of the landmarks on the scaled area (we scaled each spatial configuration to 11.3 × 12 cm, the size of the empty box), we noted their position (see Fig. 3) with respect to the East/West and to the North/South axes: a) if the actual $\Delta\lambda$ (i.e. the distance on the x axis between two landmarks) or $\Delta\Phi$ (i.e. the distance on the y axis between two landmarks) was respectively less than or equal to 1.5 cm (taking into account the sketching area), the categorical judgment was considered to be of high difficulty, and 3 points were assigned; b) if the $\Delta\lambda$ or $\Delta\Phi$ were respectively more than 1.5 cm and less or equal to 3 cm, the categorical judgment was considered to be of medium difficulty, and 2 points were assigned; and c) if the $\Delta\lambda$ or $\Delta\Phi$ were respectively more than 3 cm, the categorical judgment was considered to be of low difficulty, and 1 point was assigned. The lower the sum on each axis, the lower the level of task difficulty (maximum score 18).

Task difficulty was also measured as the difference of distances between landmarks (A to B vs A to C, *etcetera*) on the scaled area: a) If the difference between distances was less than or equal to 1.5 cm, the coordinate judgment was considered to be of high difficulty, and 3 points were assigned; b) if the difference of distances was more than 1.5 cm or less than or equal to 3 cm, the coordinate judgment was considered to be of medium difficulty, and 2 points were assigned, and c) if the difference of distances was more than 3 cm, the coordinate judgment was considered to be of low difficulty, and 1 point was assigned. The smaller the sum on each axis, the lower the level of task difficulty (maximum score 18). Table 1 and 2 report the level of categorical and coordinate difficulty for each task for the x and y axes, respectively. From the categorical point of view, the Southern Europe Area seemed to be more difficult than the others. In particular, the

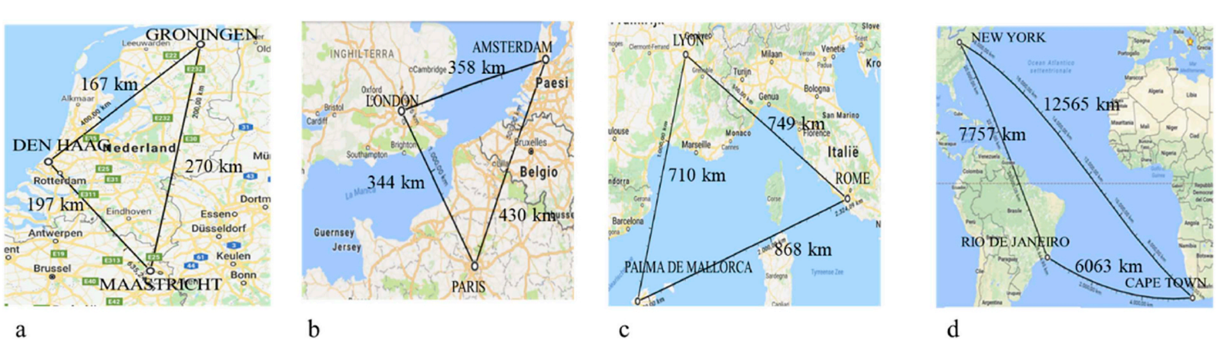

Fig. 2. Target Geographical areas and distances between landmarks: a) The Netherlands; b) Northern Europe; c) Southern Europe; d) World. Illustrations free downloaded from Google Maps.

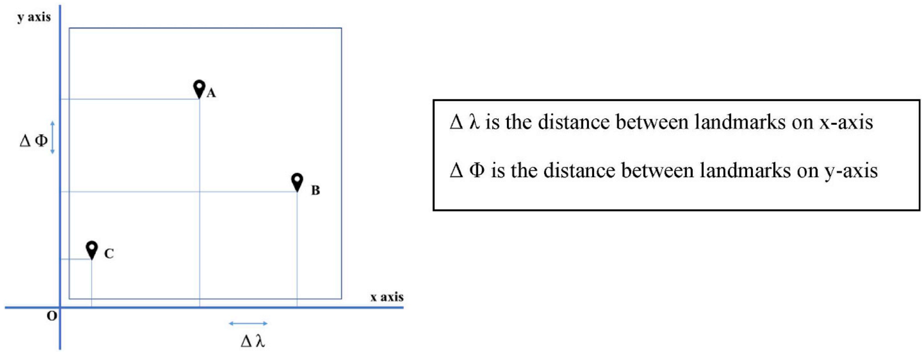

Fig. 3. Exemplification of the graphical analysis method for categorical relations between landmarks, on the two axes.

categorical judgements that seemed to present most difficulty were: on the x axis, the comparison between Lyon and Palma de Mallorca, and on the y axis, the comparison between Lyon and Rome. As for coordinates, it seemed to be very hard to make judgements regarding the distances between landmarks on the Northern and Southern Europe areas. In the case of Northern Europe all the comparisons were very tough.

2.3. Scoring method

Participants were asked to pinpoint three landmarks in an empty box (see Fig. 4a). Categorical judgements were assessed for each pair of landmarks separately for the x (e.g., B is on the right of C) and y axes (e.g., B is above C). For each correct categorical spatial judgement, participants were awarded from 1 to a maximum of 6 points (a maximum of three points for each axis).

In order to assess coordinate judgements, we considered the axial components of Manhattan distance. Coordinate judgments were made for each pair of landmarks by comparing distances, separately, on the x (e.g., the distance between landmarks B and C is greater than the distance between the landmarks A and C) and y axes (e.g., the distance between landmarks B and C is less than the distance between landmarks A and C). For each correct coordinate spatial relation, participants were awarded from 1 to a maximum of 6 points (again, a maximum of three points for each axis) (see Fig. 4b).

We adopted this specific scoring method to disentangle categorical and coordinate information. The most noticeable way to collect information regarding the mentally represented distances between landmarks is to compare them with each other. The comparison is intrinsically based on a rank/ordinal measure, but it is reasonable that people represent distances metrically. Our approach is compatible with the procedure introduced by Hellige and Michimata (1989). Their coordinate judgement is gathered asking the participants to decide if a dot was close to/far from 2 cm From the bar. In other words, they convert the metric evaluation into a categorical judgement already in the task instruction. Hence, the real distance of the dot from the bar is computed by the participants to give the categorical answer.

Table 1
Assessment of task difficulty for categorical relations.

Area	Category						Sum
	x-axis			y-axis			
Campus		Stairs of Salone Affreschi	Entrance of Student Center		Stairs of Salone Affreschi	Entrance of Student Center	9
	Entrance of the Department	1	3	Entrance of the Department	1	1	
	Stairs of Salone Affreschi		1	Stairs of Salone Affreschi		2	
Apulia		Taranto	Brindisi		Taranto	Brindisi	8
	Bari	2	1	Bari	1	1	
	Taranto		1	Taranto		3	
Italy		Cagliari	Naples		Cagliari	Naples	9
	Genoa	3	1	Genoa	1	1	
	Cagliari		1	Cagliari		2	
The Netherlands		Den Haag	Maastricht		Den Haag	Maastricht	8
	Groningen	1	3	Groningen	1	1	
	Den Haag		1	Den Haag		1	
Northern Europe		London	Paris		London	Paris	10
	Amstedam	1	3	Amstedam	2	1	
	London		2	London		1	
Southern Europe		Lyon	Palma de Mallorca		Lyon	Palma de Mallorca	13
	Rome	2	1	Rome	3	2	
	Lyon		3	Lyon		2	
World		New York	Rio de Janeiro		New York	Rio de Janeiro	10
	Cape Town	1	1	Cape Town	1	3	
	New York		2	New York		1	

Table 2
Assessment of task difficulty for coordinate relations.

Area	Coordinate						Sum
	x-axis			y-axis			
Campus		Stairs -Department	Stairs - Student Center		Stairs -Department	Stairs - Student Center	9
	Department-Student Center	1	1	Department-Student Center	2	1	
	Stairs -Department		3	Stairs -Department		1	
Apulia		Brindisi-Taranto	Brindisi-Bari		Brindisi-Taranto	Brindisi-Bari	12
	Bari-Taranto	3	1	Bari-Taranto	1	3	
	Brindisi-Taranto		2	Brindisi-Taranto		2	
Italy		Napoli-Genova	Naples-Cagliari		Napoli-Genova	Naples-Cagliari	10
	Genoa-Cagliari	1	1	Genoa-Cagliari	2	1	
	Napoli-Genova		3	Napoli-Genova		2	
The Netherlands		Maastricht-Den Haag	Groningen-Maastricht		Maastricht-Den Haag	Grooningen-Maastricht	11
	Groningen-Den Haag	3	1	Groningen-Den Haag	3	1	
	Maastricht-Den Haag		2	Maastricht-Den Haag		1	
Northern Europe		London-Paris	Paris-Amsterdam		London-Paris	Paris-Amsterdam	18
	Amstedam-London	3	3	Amstedam-London	3	3	
	London-Paris		3	London-Paris		3	
Southern Europe		Lyon-Palma de Mallorca	Rome-Lyon		Lyon-Palma de Mallorca	Rome-Lyon	16
	Rome-Palma de Mallorca	2	3	Rome-Palma de Mallorca	2	3	
	Lyon-Palma de Mallorca		3	Lyon-Palma de Mallorca		3	
World		Rio de Janeiro-New York	Cape Town-New York		Rio de Janeiro-New York	Cape Town-New York	19
	Cape Town-Rio de Janeiro	1	2	Cape Town-Rio de Janeiro	1	1	
	Rio de Janeiro-New York		1	Rio de Janeiro-New York		3	

2.4. Questionnaire

The level of familiarity with the geographical areas was investigated using two kind of questionnaires. Regarding spatial information acquired through navigation, as in the case of Campus Geographical Area, participants indicated how many times the landmarks had been visited every week on a scale from 1, never, to 7, every day. In turn, level of familiarity with spatial information acquired through map study was determined by having participants give a self-rating on four items: the use of Google Maps, Paper Maps, Weather Forecast and the Study of Geography, on a scale from 1 (= never) to 7 (= always).

Moreover, in order to assess wayfinding abilities, The Wayfinding Questionnaire (WQ, van der Ham, Kant, Postma, & Visser-Meily, 2013) was used to screen principally for navigation related complaints. It is a self-report instrument of navigational ability that includes 22 items related to navigation, but also to mental transformation, distance estimation, orientation and sense of direction. High values on the Spatial Anxiety Scale represented higher anxiety about spatial and navigational activities, on a scale from 1 (= not at all applicable to me/not uncomfortable at all) to 7 (= fully applicable to me/very uncomfortable). The present questionnaire was included only in the Experiment 3 because it was considered useful to assess potentially relevant individual differences between students of different nationalities.

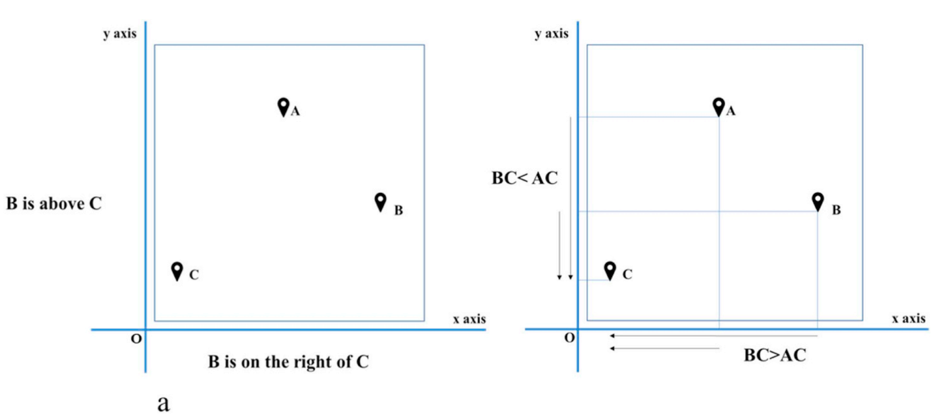

Fig. 4. a) Graphical analysis method for categorical relations; b) Exemplification of the graphical analysis method for coordinate relations between landmark distances, on the two axes.

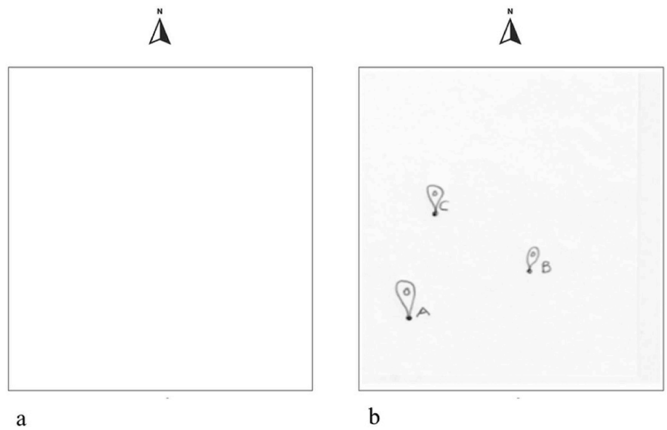

Fig. 5. a) Empty box to draw, provided to participants; b) An example of sketch map drawn by a participant.

2.5. Procedure

In the present research, as we described before, several *landmark location tasks* within a series of geographic areas, were used as stimuli. They were never seen by the participants during the experiments. The actual extent of these areas ranged from approximatively 6.6 square kilometres (Campus Geographical Area) to 16M square kilometres (World Geographical Area). Moreover, in order to compare these very different geographical stimuli, we used a "sketching area", namely an empty, oriented in portrait format box (see Fig. 5a), measuring 11.3 × 12 cm (e.g., de Goede & Postma, 2015), north facing. Participants only had to mark the landmarks for each geographical area, respectively, keeping in mind metric distances as well as categorical ("A is North/South and East/West of B") spatial relations between landmarks (see Fig. 4), participants responded to the following instructions: "Think of the spatial relationships between the landmarks. In the box below, draw three crosses, corresponding to the landmarks, and label them. Please, use the full sketching area. Please, be careful to respect the distances between landmarks and their correct positions relative to each other" (see Fig. 5b, as an example of sketch map drawn by the participants).

The size of the target areas varied greatly, nonetheless participants were forced to use the same box to represent them.

Therefore, the landmark location task was based on pinpointing only three highly memorable landmarks (architectural elements for the Campus Geographical Area, and cities for the other Geographical Areas, see below). The selection of the landmarks in each geographical area was based on a pilot aimed to rating students' level of knowledge and familiarity with landmarks. The final choice was the result of the compromise between the need to take into account landmark memorability, and the discriminability of a landmark's position and distance from the other landmarks.

Moreover, the global level of familiarity with the geographical areas was measured and the wayfinding abilities of the participants were assessed.

3. Experiment 1

Experiment 1 aimed to assess the effect of exposures to the environment (goal-directed behaviours of exploration vs map study) on the accuracy of categorical and coordinate encoding, using landmark location task related to the Campus Geographical Area, Apulia Geographical Area and Italy Geographical Area.

3.1. Method

3.1.1. Participants

One hundred and sixty-eight healthy participants, 86 females, between 19 and 30 years of age (age mean ± sd: 21.75 ± 2.41) took part in the study. All participants were Italian university students from introductory courses in psychology at the University of Bari. The level of education for the overall sample was 15.22 (sd = 1.3). The whole sample was admitted to the assessment, which evaluated their ability to retrieve allocentric spatial information previously learned mainly through navigation, and map study.

All participants, blinded to the hypothesis of the study, signed a consent form. The participants were enrolled between November and December 2017. The Local Ethical Committees of the Institutions approved the study protocol.

3.1.2. Materials and procedure

Three Landmark Location Tasks were administered:

a) Campus Geographical Area
b) Apulia Geographical Area
c) Italy Geographical Area

Participants were university students, who had lived in Bari from birth. All the participants had a global level of familiarity with the geographical areas investigated.

The entire procedure was made clear to the participants beforehand. Participants were assessed individually in a well-lit and quiet room without disturbances. Data were collected in one session. The whole assessment lasted a maximum of 20 min.

3.2. Results

Descriptive statistics and preliminary analysis of the inclusion criteria were performed, as reported in Table 3.

First, we controlled the effect of intrinsic task difficulty on the performance, adjusting for this covariate through multiple regression (Sardone, Bosco, Scalisi, & Longoni, 1995; Kirk, 1982; Lison & Robotti, 1982; Athey & Imbens, 2017; Wager, Du, Taylor, & Tibshirani, 2016). This method has the advantage, unlike the most common analysis of covariance, to take into account the differences between subjects in the

Table 3
Means ± standard deviations for interval variables. Significance values obtained through t test on school subjects, study of geography and familiarity levels with the target Geographical Areas as effect of gender.

	MALE	FEMALE	Test
	(N = 82)	(N = 86)	
Age, years	22.01 ± 2.78	20.53 ± 0.96	$p < 0.01$
Education, years	15.44 ± 1.81	15.00 ± 0.00	*n.s.*
SCHOOL SUBJECTS (avarage grade)			
Geography	7.44 ± 0.81	7.66 ± 0.67	*n.s.*
Math	7.15 ± 1.09	7.77 ± 1.07	$p < 0.01$
Physics	6.95 ± 1.11	7.70 ± 1.08	$p < 0.001$
Like Science Subjects	4.55 ± 1.13	4.07 ± 1.04	$p < 0.01$
STUDY OF GEOGRAPHY AT SCHOOL			
Campus	–	–	–
Apulia	3.53 ± 1.58	3.57 ± 1.31	*n.s.*
Italy	3.91 ± 1.55	3.67 ± 1.22	*n.s.*
LEVEL OF FAMILIARITY			
Campus	4.64 ± 0.56	3.78 ± 0.54	$p < 0.001$
Apulia	3.25 ± 0.95	3.07 ± 0.87	*n.s.*
Italy	3.22 ± 0.96	2.92 ± 0.84	$p < 0.01$

level of correlation existing between X and Y variables. From now on, when we mention the participants' performance, we will refer to the score correction through the Y adjusted method. Preliminary, we used the logarithmic transformation in order to transform the variable task difficulty. *Logarithmic transformations are a convenient means of transforming a highly skewed variable into one that is more approximately normal* (Benoit, 2011, p. 2). Then separately for each participant, we considered the performance (Y) and task difficulty (logX), computing the regression of X on Y. We adjusted the scores using the following formula, were *b* was the beta coefficient:

$$Y_{adj} = Y + b(X - \bar{x})$$

Then, in order to accomplish the purpose of the present experiment, a mixed factor Anova was performed, with Gender as between-subject variables, Geographical Area (three levels: Campus, Apulia, and Italy) and Spatial relation (two levels: category and coordinate) as repeated measure variables.

The results were as follows: the main effect of Geographical Area ($F(2, 166) = 18.62$, $p < 0.001$; $\eta_p^2 = 0.10$) proved to be significant (Means and sds: Campus 4.92 ± 0.06; Apulia 4.45 ± 0.05, and Italy 4.36 ± 0.08). The post-hoc analysis showed a significant difference between Campus Geographical Area and Apulia and Italy Geographical Areas. No differences were found between the latter two areas. Moreover, the Geographical Area × Gender interaction ($F(2, 166) = 4.46$, $p < 0.01$; $\eta_p^2 = 0.03$) was also significant (the Campus: male mean ± sd = 4.9 ± 0.09; female mean ± sd = 4.9 ± 0.09, Apulia: male mean ± sd = 4.4 ± 0.07; female mean ± sd = 4.5 ± 0.07; Italy: male mean ± sd = 4.6 ± 0.12; female mean ± sd = 4.1 ± 0.12). From the inspection of the means an advantage for male emerged for Italy Geographical Area, while no gender-related differences emerged in the performance on the Campus and Apulia areas. Finally, the interaction Geographical Area x Spatial relation ($F(2, 166) = 7.03$, $p < 0.001$; $\eta_p^2 = 0.04$) was also significant. Inspection of the graph (see Fig. 6) revealed an advantage for coordinate over categorical judgements of 0.27 for Campus Geographical Area, a substantial draw between the two components for Apulia Geographical Area, and an advantage of about 0.19 for categorical judgement over coordinate for Italy Geographical Area. No other main effects or interaction effects were significant.

3.3. Discussion

This study compared the performance of a group of young participants on three different landmark location tasks based on information acquired through map study, repeated episodes of navigation and mixed strategies. Using Campus Geographical Area, Apulia and the Italy Geographical Areas, we examined encoding of categorical and

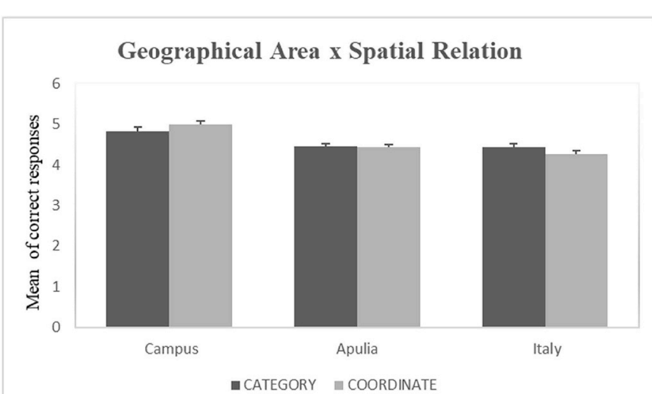

Fig. 6. Mean proportions of correct responses and 95% Confidence Intervals for categorical (dark grey bars) and coordinate (light grey bars) spatial relations, on Campus, Apulia and Italy Geographical Areas.

coordinate spatial relations, applying this paradigm to sketch maps. All the participants were enrolled in the study on the basis of their self-reported level of familiarity with geographical areas and school experience with scientific matters. As shown in Table 3 there were no differences between males and females in terms of geographic skills. However, male participants claimed more familiarity with the Campus and the Italy areas in terms of self-reported global spatial experience.

Participants performed better on the Campus Geographical Area than the other two tasks, showing the positive effect of repeated experiences of navigation on the maintenance of the memory trace. The results were net of task difficulty.

Moreover, participants' performance also showed a coordinate advantage for Campus Geographical Area. By contrast, they showed an advantage on categorical judgements in the task based on information acquired primarily through map study (Italy Geographical Area). Furthermore, participants showed a balance between the categorical and coordinate components of spatial relations in the task characterized by a mixed format of learning (Apulia Geographical Area). The results support the hypothesis that exploration of the environment improves people's ability to solve coordinate - distance - judgements.

Finally, regarding gender effects, males seemed to outperform female participants in the task regarding Italy Geographical Area. This result was in line with other research that supports gender differences, with males performing better in spatial tasks (for a review, de Goede, 2009). In addition, male participants seemed to overestimate their spatial competence in the self-report questionnaire used to collect information (Brackett & Rivers, 2006; Cornell, Sorenson, & Teresa Mio, 2003), but this evidence did not have an effect on their performance. It is plausible to assume that higher familiarity with landmarks contributed to reducing gender differences.

Therefore, Experiment 2 was devoted to deepening our understanding of the role of familiarity by comparing only spatial information acquired through map study.

4. Experiment 2

The aim of Experiment 2 was to verify the effect of familiarity on the accuracy of spatial encoding using a landmark location task based on spatial information primarily acquired through map study. We predicted that greater familiarity would result in a smaller difference in the accuracy of categorical and coordinate spatial relations.

4.1. Method

4.1.1. Participants

One hundred and twenty healthy participants, 60 females, between 19 and 30 years of age (age mean ± sd: 21.42 ± 2.14) took part in the study. All participants were university students from introductory courses in psychology. The level of education for the overall sample was 15.15 (sd = 0.9). The whole sample was admitted to the assessment, which aimed at evaluating their ability to retrieve allocentric spatial information previously learned mainly as an effect of map study. The enrolment procedure was the same as that for *Experiment 1*. The participants were enrolled between January and February 2018.

4.1.2. Materials and procedure

Three Landmark Location Tasks were administered:

a) Italy Geographical Area
b) Northern Europe Geographical Area
c) World Geographical Area

The setting, procedures and inclusion criteria were the same as in *Experiment 1*. The level of familiarity with geographical area were also tested, as in the previous experiment (see Table 4).

Table 4
Means ± standard deviations for interval variables. Significance values obtained through t test on school subjects, study of geography and familiarity levels with the target Geographical Areas as effect of gender.

	MALE	FEMALE	Test
	(N = 60)	(N = 60)	
Age, years	22.31 ± 2.62	20.55 ± 0.83	*p<0.001*
Education, years	15.31 ± 1.39	15.00 ± 0.00	*n.s.*
SCHOOL SUBJECTS (avarage grade)			
Geography	7.45 ± 0.81	7.66 ± 0.70	*n.s.*
Math	7.16 ± 1.09	7.74 ± 1.02	*p<0.01*
Physics	6.88 ± 1.01	7.70 ± 0.80	*p<0.001*
Like Science Subjects	4.48 ± 1.01	4.03 ± 1.11	*p<0.01*
STUDY OF GEOGRAPHY AT SCHOOL			
Italy	3.88 ± 1.61	3.61 ± 1.11	*n.s.*
Northern Europe	4.01 ± 1.60	3.51 ± 1.08	*n.s.*
World	3.55 ± 1.59	3.25 ± 1.23	*n.s.*
LEVEL OF FAMILIARITY			
Italy	3.09 ± 0.91	2.86 ± 0.73	*n.s.*
Northern Europe	3.16 ± 1.02	2.68 ± 0.75	*p<0.01*
World	2.75 ± 0.86	2.54 ± 0.81	*n.s.*

4.2. Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Table 4. As in the previous experiment we controlled the effect of intrinsic task difficulty on the performance.

In order to achieve the aim of this experiment, a mixed factor Anova was performed, with Gender as between-subject variables, Geographical Area (three levels: Italy, Northern Europe, and World) and Spatial relation (two levels: category and coordinate) as repeated measure variables.

The results were as follows: the main effect of Geographical Area (F (2, 117) = 9.30, p < 0.001; η_p^2 = 0.07) proved to be significant (Means and sds: Italy 4.28 ± 0.10; Northern Europe 3.70 ± 0.07, and World 4.13 ± 0.12). The post-hoc analysis showed a significant difference between the Northern Europe and the Italy and the World Geographical Areas. The comparison between the last two tasks was not significant. In addition, a main effect of Spatial relation (F (1, 117) = 126.49, p < 0.001; η_p^2 = 0.51) was found (Means and sds: category 4.35 ± 0.06; coordinate 3.72 ± 0.06). Moreover, the Geographical Area × Gender interaction (F (1, 117) = 5.47, p < 0.01; η_p^2 = 0.04) was also significant (Italy: male mean ± sd = 4.55 ± 0.14; female mean ± sd = 4.01 ± 0.14, Northern Europe: male mean ± sd = 3.61 ± 0.10; female mean ± sd = 3.80 ± 0.11; World: male mean ± sd = 3.97 ± 0.16; female mean ± sd = 4.30 ± 0.16). Finally, the interaction between Geographical Area x Spatial relation (F (2, 117) = 30.52, p < 0.001; η_p^2 = 0.20) was also significant. From inspection of the graph (see Fig. 7), a general advantage emerged for categorical over coordinate judgements on the three areas, in particular it was small for Italy Geographical Area (0.18), it was large for the Northern Europe (1.3) and it was medium for the World (0.42). No other main or interaction effects were significant.

4.3. Discussion

Experiment 2 compared the performance of a group of university students on information acquired mainly through map study, regarding Italy Geographical Area, Northern Europe Geographical Area and World Geographical Area. In this study, familiarity with the geographical areas investigated played an important role. Putting aside the format of learning, we controlled familiarity with geographical

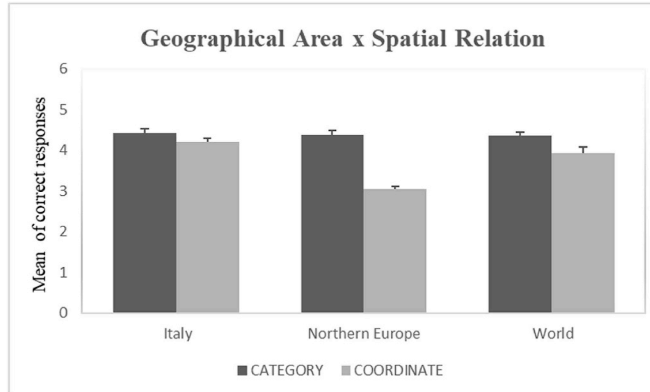

Fig. 7. Mean proportions for correct responses and 95% Confidence Intervals for categorical (dark grey bars) and coordinate (light grey bars) spatial relations, on Italy, Northern Europe and World Geographical Areas.

knowledge. All the participants were enrolled in the study recording their self-reported level of familiarity and school experience with scientific matters. There were no differences between males and females in geographic skills. However, male participants declared more familiarity with Northern Europe.

Again, the major pattern of results was in line with expectations. Globally, the level of self-reported familiarity with the Italy Geographical Area was higher than that for the Northern Europe and the World Geographical Areas.

Moreover, in our view it should be noted how geographers represent space in two-dimensional images. It is worth noting that the creation of a map entails a key problem: how to turn the three-dimensional sphere of the Earth into a flat surface. Generally, a planisphere map results in a huge distortion of the relative sizes of the continents, dramatically shrinking Africa and making Northern Europe smaller than it actually is. Mapmakers have to choose a projection of the globe that approximates the basic properties of shape, size, direction, distance and scale. This inaccurate view of the size of the Western World results in an inaccurate and unclear spatial mental representation of Northern Europe (Snyder, 1987; Snyder & Maling, 1993). Thus, maps distort reality and convey bias: humans will acquire misleading perceptions of the distances and alignments between cities. Consequently, in the case of Northern Europe the low performance participants exhibited in judging distances can presumably be ascribed to cognitive distortions in the mental representation of that geographical area.

Generally speaking, the judgement of categorical spatial relations was shown to be easier in all tasks based on allocentric spatial information acquired through map study. Once again, this result is in line with previous findings (Bruyer et al., 1997; Klencklen et al., 2012; Trojano et al., 2002). But the more interesting result concerns the effect of familiarity with geographical areas: differences between performance with categorical and coordinate spatial relations decreased as the supposed level of familiarity of the geographical area increased (Lloyd & Patton, 2011).

Finally, regarding gender effects, the results were not in line with expectations. Men outperformed women in the Italy Geographical Area, as in the previous study, but female participants outperformed male participants on the Northern Europe and World Geographical Areas. Probably, given that familiarity was self-evaluated, males overestimated their level of familiarity, while, on the contrary, female participants underestimated their knowledge. This evidence has already been reported by Brackett et al. (2006).

5. Experiment 3

The last experiment investigated another aspect of familiarity: the different origin countries of the participants. Having different degrees of knowledge might have had an effect on spatial encoding.

5.1. Method

In order to accomplish the purpose of the present experiment, we decided to manipulate familiarity with spatial information by exploiting the fact that people have better knowledge of their home country than other countries. Testing samples of Italian and Dutch students, we first measured “Accuracy across Countries”, in which distances of triplets of cities were evaluated for both The Netherlands and Italy. Second, we measured “Accuracy across European Regions” by testing spatial encoding for the Northern Europe and Southern Europe areas. Dutch students were expected to exhibit less difference between categorical and coordinate spatial relations for the Netherlands and Northern Europe Geographical Area, compared to Italy and Southern Europe Geographical Area. Conversely, an inversion of this pattern of results was expected for the Italian sample. Furthermore, for all students, a greater difference would be expected in the comparison of Accuracy across countries than the comparison of Accuracy across European Regions.

5.1.1. Participants

Eighty healthy participants, 40 females, between 19 and 30 years of age took part in the study. All participants were university students coming from different faculties. The overall sample included 40 Dutch and 40 Italian participants. The mean age for the Dutch was 23.01 (sd = 3.01) and for the Italians was 24.35 (sd = 4.05). The level of education for the Dutch was 14.40 (sd = 1.89) and for the Italians was 15.90 (sd = 0.98).

All participants signed a consent form and were ignorant of the aims of the study. The participants received 5 euros (Dutch students) or 0.5 course credits for participation (Dutch and Italian students). They were enrolled between March and May 2018. The local ethical committees of the Institutions approved the study protocol.

5.1.2. Materials and procedures

The inclusion criterion for young participants was to have lived in their country from birth and not to have navigational-related complaints as assessed by The Wayfinding Questionnaire. No one was excluded from the sample. Moreover, all participants were rated on their knowledge of geographical areas investigated as in the previous experiments .

Four Landmark Location Tasks were administered:

a) Italy Geographical Area
b) Netherlands Geographical Area
c) Northern Europe Geographical Area
d) Southern Europe Geographical Area

The setting and procedure of administration were the same as in the previous experiments.

5.2. Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Tables 5 and 6. As in the previous experiments we controlled the effect of intrinsic task difficulty on the performance.

In line with the first aim of Experiment 3 (Accuracy across Countries), a mixed factor Anova was performed, with Group (two levels: the Italians, the Dutch) and Gender as between-subject variables, Geographical Area (two levels: Italy, The Netherlands) and Spatial relation (two levels: category and coordinate) as repeated measure variables. The results were as follows: the main effects of Group (F (1, 78) = 36.99, p < 0.001; η_p^2 = 0.33) proved to be significant (Means and sds: the Italians 3.57 ± 0.09; the Dutch 4.38 ± 0.09). In addition, the main effect of Spatial relation (F (1, 78) = 26.61, p < 0.001; η_p^2 = 0.26) was present (Means and sds: category 4.17 ± 0.07; coordinate 3.77 ± 0.08). Moreover, the Group x Geographical Area interaction (F (1, 78) = 98.16, p < 0.001; η_p^2 = 0.56) was also significant (Italy: the Italians mean ± sd = 4.45 ± 0.15; the Dutch mean ± sd = 3.80 ± 0.15; The Netherlands: the Italians mean ± sd = 2.68 ± 0.13; the Dutch mean ± sd = 4.97 ± 0.13). Additionally, Group x Spatial relation (F (1, 78) = 8.41, p < 0.01; η_p^2 = 0.10) was also significant (the Italians: category mean ± sd = 3.65 ± 0.11; coordinate mean ± sd = 3.47 ± 0.12; the Dutch: category mean ± sd = 4.70 ± 0.10; coordinate mean ± sd = 4.07 ± 0.12). Furthermore, Geographical Area x Spatial relation (F (1, 78) = 19.72, p < 0.001; η_p^2 = 0.21) was also significant (Italy: category mean ± sd = 4.15 ± 0.10; coordinate mean ± sd = 4.11 ± 0.13; The Netherlands: category mean ± sd = 4.22 ± 0.10; coordinate mean ± sd = 3.43 ± 0.11). Finally, Group x Geographical Area x Spatial relation (F (1, 78) = 19.72, p < 0.000; η_p^2 = 0.18) was also significant. From the inspection of the graph (see Fig. 8), a general advantage for categorical over coordinate judgement emerged on the three areas, in particular for Italy Geographical Area, the Italians showed an advantage for categorical over coordinate judgements of 0.5, and the Dutch an advantage of 0.6; for the Netherlands Geographical Area, the Italians showed an advantage for categorical over coordinate judgements of 0.9, and the

Table 5
Means ± standard deviations for interval - frequencies for nominal - variables. Significance values obtained through t test - χ2 for frequencies - on school subjects, and Wayfinding Questionnaire, separately for the Italian and Dutch participants.

	THE DUTCH	THE ITALIANS	Test
	(N = 40)	(N = 40)	
Gender, F/M	20/20	20/20	*n.s.*
Age, years	23.01 ± 3.01	24.35 ± 4.05	*n.s.*
Education, years	14.40 ± 1.89	15.90 ± 0.98	*n.s.*
SCHOOL SUBJECTS (avarage grade)			
Geography	9.90 ± 1.14	7.11 ± 1.60	*n.s.*
Math	6.90 ± 1.14	7.30 ± 1.18	*n.s.*
Physics	6.57 ± 1.11	7.15 ± 1.08	*n.s.*
Like Science Subjects	4.20 ± 1.60	4.18 ± 1.20	*n.s.*
WAYFINDING QUESTIONNAIRE (WQ)			
Navigation and Orientation	50.18 ± 12.9	52.33 ± 11.20	*n.s.*
Spatial Anxiety	27.02 ± 8.60	27.07 ± 7.50	*n.s.*
Distance Estimation	12.45 ± 4.08	9.48 ± 4.06	*p<0.01*

Table 6
Means ± standard deviations for interval variables. Significance values obtained through t test on study of geography and familiarity levels with the target Geographical Areas, separately for the Italian and Dutch participants.

	THE DUTCH	THE ITALIANS	Test
	(N = 40)	(N = 40)	
STUDY OF GEOGRAPHY AT SCHOOL			
Italy	2.90 ± 1.40	4.60 ± 1.40	*p<0.01*
The Netherlands	5.50 ± 1.70	2.80 ± 1.60	*p<0.01*
Northern Europe	4.90 ± 1.30	4.80 ± 1.60	*n.s.*
Southern Europe	3.80 ± 1.40	4.10 ± 1.70	*n.s.*
LEVEL OF FAMILIARITY			
Italy	3.10 ± 0.96	3.90 ± 1.17	*p<0.01*
The Netherlands	4.20 ± 0.80	2.30 ± 1.19	*p<0.01*
Northern Europe	4.10 ± 0.70	4.30 ± 1.20	*n.s.*
Southern Europe	3.10 ± 0.93	3.30 ± 1.36	*n.s.*

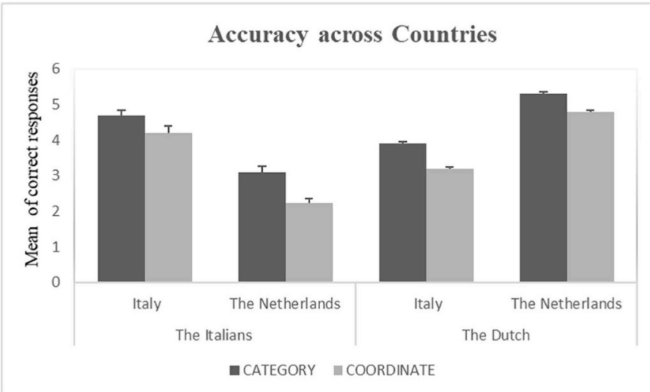

Fig. 8. Mean proportions for correct responses and 95% Confidence Intervals for categorical (dark grey bars) and coordinate (light grey bars) spatial relations, on Italy and the Netherlands Geographical Areas, separately for the Italian and Dutch participants.

Dutch an advantage of 0.7. Moreover, the Netherlands Geographical Area was comparable to the Italy and the Dutch were more accurate than the Italians. No other main or interaction effects were significant.

Regarding the second aim (Accuracy across European Regions), a mixed factor Anova was performed, with group (two levels: the Italians, the Dutch) and gender as between-subject variables, Geographical Area (two levels: Northern Europe, Southern Europe) and Spatial relation (two levels: category and coordinate) as repeated measure variables. The results were as follows: a main effect of spatial relation ($F(1, 78) = 40.18$, $p < 0.000$; $\eta_p^2 = 0.35$) was found (Means and sds: category 5.09 ± 0.07; coordinate 4.61 ± 0.13). Furthermore, Geographical Area x Spatial relation ($F(1, 78) = 27.75$, $p < 0.000$; $\eta_p^2 = 0.27$) was also significant (Northern Europe: category mean ± sd = 4.96 ± 0.09; coordinate mean ± sd = 4.80 ± 0.16; Southern Europe: category mean ± sd = 5.20 ± 0.10; coordinate mean ± sd = 4.40 ± 0.15). Finally, Group x Geographical Area x Spatial relation ($F(1, 78) = 9.99$, $p < 0.01$; $\eta_p^2 = 0.12$) was also significant. From the inspection of the graph (see Fig. 9) a general advantage for categorical over coordinate spatial relations emerged: for the Northern Europe Geographical Area the Italians showed an advantage for coordinates over categorical judgements of 0.2. The Dutch, by contrast, showed an advantage for categorical over coordinate judgements of 0.4. For the Southern Europe Geographical Area, the Italians showed an advantage for categorical over coordinate judgements of 0.9 and the Dutch an advantage for categorical over coordinate judgements of 0.7. Moreover, the Northern Europe Geographical Area was comparable to the Southern Europe and the Dutch and Italians performed similarly. No other main or interaction effects were significant.

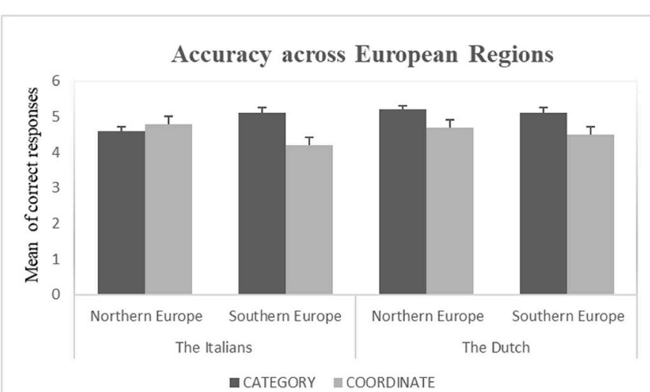

Fig. 9. Mean proportions for correct responses and 95% Confidence Intervals for categorical (dark grey bars) and coordinate (light grey bars) spatial relations, on Northern Europe and Southern Europe Geographical Areas, separately for the Italian and Dutch participants.

5.3. Discussion

The present study compared the performance of Italian and Dutch students, on four landmark location tasks based on information acquired mainly through the study of maps. In order to investigate the "Accuracy across Countries" we used Italy Geographical Area and the Netherlands Geographical Area; for the "Accuracy across European Regions" we used the Northern and Southern Europe Geographical Areas.

Focusing on the way in which geographical information was acquired and the level of familiarity with spatial information, we investigated the difference between categorical and coordinate spatial relations. Moreover, with this experiment we studied the same phenomenon from a cross-cultural perspective, observing how nationality intersected with the other variables mentioned above.

The two groups were comparable in terms of demographic variables, school subject preferences and skills, and wayfinding abilities. We also asked questions about the study of geography at school and their level of familiarity with the geographic areas investigated. As shown in Table 6 there was a significant difference between the Dutch and Italian students with respect to their level of familiarity with their own country and the foreign country. No differences between the Dutch and Italian students emerged for the Northern and Southern Europe. Nonetheless, the Northern Geographical Area appeared to be more familiar overall to both samples than the Southern one.

In the "Accuracy across Countries" analysis, the Dutch were more accurate than the Italian students in their sketch map. Probably Dutch students have been more exposed to maps, and in particular to the Map of Italy, and the salient shape that sets it apart in Europe, consolidating the memory trace (Thomas et al., 2016). However, opportunities for travel between the Dutch and Italian cities cannot be excluded.

Generally, both the Dutch and Italian participants were more accurate in categorical than in coordinate relations. More importantly, the difference between performance on the categorical and coordinate spatial relations decreased with familiarity. This result is in line with the findings from the previous experiments, showing again the influence of familiarity on spatial encoding. The Italian students showed better competence on Italy Geographical Area. Across their lifetimes, they had more exposure to that map and had acquired more information regarding the configuration of Italian cities. Conversely, the Dutch were better able to pinpoint the Dutch cities. The decrease in the difference between categorical and coordinate accuracy as an effect of familiarity again shows the importance of investigating spatial mental mechanisms regarding information well consolidated in memory.

The "Accuracy across European Regions" showed very similar performance levels across the Dutch and the Italians. Their similar performance was justified by similar levels of knowledge about the geography of Europe. However, Northern Europe appeared to be more familiar than Southern Europe for both groups. Also, in the case of "Accuracy across European Regions" the same pattern of results, regarding the difference between categorical and coordinate spatial information, recurred: the higher the level of familiarity, the lower the difference between categorical and coordinate levels of accuracy. No gender differences emerged. In the present experiment we added gender as a between subject factor, only to make it coherent with the previous statistical analyses.

6. General discussion and conclusion

Spatial relations can be encoded in terms of categorical and coordinate information. The categorical spatial relations are abstract, and they are described with spatial labels useful for viewpoint independent object recognition and spatial location tasks (Kosslyn, 1987; Jager &

Postma, 2003). Coordinate spatial relations, instead, refer to metric properties, and are, amongst other purposes, necessary to guide precise movements (e.g., Bullens & Postma, 2008).

This is one of the first studies looking at the application of categorical and coordinate relation measures using sketch maps of different scales and familiarity. Sketch maps are representations of the environment in which distances, directions and positions are integrated. In this research we wanted to investigate the difference between categorical and coordinate spatial relations in sketch maps based on different geographical information: primarily learned from repeated episodes of exploration, from map study and from both. Moreover, we added another variable potentially affecting performance: the level of familiarity with geographical areas investigated, controlling for the effect of task difficulty.

Furthermore, we adopted a specific scoring method to disentangle categorical and coordinate information based on the Hellige and Mishimata task (1989), converting metric information into a categorical judgement.

The way in which spatial information is acquired (moving in the environment mainly through goal-directed behaviours of exploration or via symbolic sources such as map study), and the level of familiarity with spatial and geographical configurations both play an important role in spatial cognition. In Experiment 1 we focused on different kinds of learning of spatial information, applying the categorical and coordinate paradigm to Campus Geographical Area, Apulia and Italy Geographical Areas. The results showed a positive effect of having learned spatial information through navigation on the accuracy with which coordinates were encoded and retrieved. Moreover, there was a close draw between categorical and coordinate relations in Apulia Geographical Area, where the kind of spatial learning was likely to be mixed. It is evident the consistent contribution of exploration on the acquisition of spatial information. Finally, for Italy Geographical Area categorical proved to be more important than coordinate spatial information.

In the second experiment we employed mainly allocentric maps, taking into account participants' familiarity with the geographical areas. Using Italy Geographical Area, the Northern Europe and World Geographical Areas, the difference in performance between categorical and coordinate spatial relations decreased with the increase in self-reported level of familiarity with the geographical area (Lloyd & Patton, 2011). For the first time, this result has been confirmed using sketch maps. In addition, categorical spatial relations were better determined than coordinates, showing that the former were easier when mainly allocentric spatial information (acquired mainly via map study) was involved (e.g., Klencklen et al., 2012).

Regarding gender differences, men outperformed women in Italy Geographical Area (Experiments 1 and 2), and this result was in line with previous findings in which women showed difficulties in the manipulation of allocentric spatial information (e.g., Picucci et al., 2010). An interesting result emerged with respect to female performance on the Northern Europe and on the World (second experiment). In both of these cases, women outperformed men. Nonetheless, they underestimated their geographic abilities as emerged from the self-report questionnaire (Brackett & Rivers, 2006; Cornell, Sorenson, & Mio, 2003). However, it is possible to claim that the level of familiarity with spatial information might be crucial in observed gender differences among participants.

The data emerging from the third experiment were in line with previous findings. Introducing nationality as another variable of study, we compared Italian and Dutch students. The results suggested that categorical spatial relations were easier for both groups in all tasks. Moreover, in order to disentangle categorical and coordinate spatial relations we applied this spatial configuration paradigm to sketching maps with different levels of familiarity for the participants. Overall, Dutch participants showed higher accuracy across tasks. On the basis of familiarity with Italy and the Netherlands Geographical Areas, the Italian and the Dutch groups seemed to manipulate spatial information better for their own country. Conversely, no differences emerged between the Dutch and the Italians for more global geographical areas such as Northern and Southern Europe (both in self-reported and objective measures). Exposure to these geographical areas seemed to be more universal, perhaps due in part to the fact that the Italian and the Dutch levels of education were comparable. Most importantly, these results show that the difference between accuracy on categorical and coordinate spatial relations decreases with increasing levels of familiarity with the relevant geographical area (Lloyd & Patton, 2011).

The present research has some limitations. Notwithstanding our efforts to build ecological spatial tasks based on a standardized method (e.g., Lopez, Caffò, & Bosco, 2018, 2019). Unlike laboratory-based psychometric tasks, the use of more ecological tasks means that some variables are not efficiently under the control of the researcher, such as spatial learning and the difficulty of soliciting remotely acquired spatial knowledge. Furthermore, the Wayfinding Questionnaire was included only in the third experiment in order to highlight possible individual differences. However, as such it could also have been relevant in the other two studies.

In summary, our findings have contributed to a better understanding of categorical and coordinate processes involved in the representations of one's environments. In particular, it emerged that navigation eased coordinate encoding. This result could be explained by the fact that exact spatial properties are essential for navigation (such as exact distance and direction). Familiarity also enhanced coordinate processing. Navigation supported familiarity, contributing to an accurate encoding of spatial relations. On the other hand, categorical spatial relations were rapidly processed, and seemed to be less influenced by the effect of familiarity.

In conclusion, internal representations of the outside world can be obtained by sketch maps at different scales. The sketch map representation contains, relatively independent, categorical and coordinate spatial relations. We have suggested a way to disentangle categorical and coordinate spatial relations, emphasizing how the differences in performing coordinate and categorical judgments decrease as a function of familiarity with spatial information, also in the sketch map.

CRediT authorship contribution statement

Antonella Lopez: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Albert Postma:** Supervision, Writing - review & editing. **Andrea Bosco:** Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of competing interest

None.

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